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Performance Characterization of Magnesium/Manganese Dioxide Batteries

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13. ABSTRACT *(Maximum 200 words)*

The effects of storage and temperature on the performance of magnesium/manganese dioxide batteries produced by two different manufacturers was studied. The producers are not necessarily suppliers to the U.S. Army; however, a performance characterization of the two battery types was desired. Both batteries performed extremely poorly at -17°C (0°F), losing over 70 percent capacity, compared with performance at 21°C (70°F) and above. After partial usage, and storage, both battery types lost as much as 25 hours of service. Overall, no appreciable difference existed between the batteries of the two manufacturers.

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INTRODUCTION

The BHARAT Electronics Company, India, contacted the Power Sources Division, ETDL, LABCOM, concerning its version of the magnesium BA-4386 battery. From the battery test data supplied by BHARAT, their magnesium battery appeared to outperform the present magnesium BA-4386 battery employed by the U.S. Army.

The Army's interest in an improved magnesium battery is twofold. First, to date, there is only one manufacturer of the BA-4386/U battery. However, if another company had the capability of manufacturing this battery competitively, the unit cost would be kept low, and magnesium battery technology growth would be stimulated. Competition would also help to provide the Army with sufficient units of magnesium batteries. Second, the Army is presently involved in research work directed towards a magnesium battery replacement for the lithium/sulfur dioxide battery (especially for training exercises). Novel battery technologies, if any, used by BHARAT Electronics in its magnesium battery, could probably be employed in magnesium battery research.

PREVIOUS INVESTIGATIONS

In earlier work[1] in 1986, the storability and temperature discharge characteristics of magnesium/manganese dioxide and lithium/sulfur dioxide batteries were investigated. The investigation enhanced the long-studied phenomenon of magnesium battery anode corrosion during storage, following partial usage. Results proved that the military magnesium battery (BA-4386) lost up to 66 percent of original capacity during storage. Testing also confirmed the highly temperature-dependent magnesium battery performance.

During more recent work,[4] the effects of cathode moisture content upon magnesium battery performance were investigated. Results proved that additional cathode water enhanced battery performance during continuous and intermittent discharge. This is credited to a decrease in the "drying out" effect of the cathode, which, following partial usage, occurs during storage.

APPROACH

The investigation was made to characterize the performance of the BHARAT magnesium battery, with respect to temperature and storability. The BHARAT magnesium battery is identical in size, form, and function to the magnesium BA-4386 battery already employed by the Army. Test results are tabulated and compared with previous magnesium battery performance data.[1]

EXPERIMENTAL PROCEDURE

Ten magnesium batteries were obtained from BHARAT Electronics. Prior to electrical testing, the dimensions and weights of the batteries were recorded. Following electrical testing, the dimensions were remeasured and compared with initial values and battery specifications.

Electrical testing simulated AN/PRC-77 radio usage, which is the main application of the BA-4386 battery. The discharge scenario was identical to that used during earlier magnesium battery testing[1]. The discharge regime consisted of two minutes at 14.2 ohms (transmit mode) followed by 18 minutes at 291 ohms (receive mode). The schematic of the discharge circuit is displayed in Fig. 1.

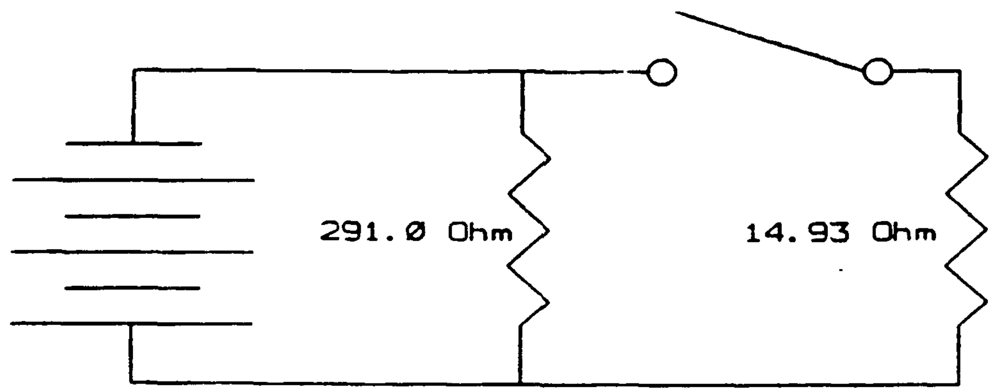

Figure 1. Discharge schematic.

With the discharge switch closed, the radio transmit mode is simulated. The two parallel resistors produce a resistive load of 14.2 ohms. Radio-receive mode is simulated when the test circuit switch is open. Testing was performed at -17.8, 4.4, 21.1, and 43.3 degrees Celsius. This process was performed either continuously or intermittently. Cycling was controlled by a Xanadu Controls Universal Programmable Timer. Voltage/time data were recorded on a Gould Chart Recorder, Model SC282. During discharge, battery environmental temperature was controlled with a Blue M Environmental Chamber, Model 1004-3B.

Intermittent battery testing was performed as described here. The discharge regime consisted of 8 hours of AN/PRC-77 simulation, followed by 16 hours of room temperature (21°-27°C) storage. Initially, this simulation was carried out for one day (at -17.8°C), two days (at 4.4°C), four days (at 21.1°C), or three days (at 43.3°C). The four noted temperatures are the conditions the batteries experienced during each daily 8 hour discharge. Next, all batteries were stored at room temperature for four weeks. The discharge regime (8 hours radio simulation followed by 16 hours rest) was continued to battery end voltage. Battery performance was measured to a 10-volt cutoff under the transmit (14.2 ohm) mode.

DISCUSSION AND RESULTS

Performance characteristics of the BHARAT magnesium battery are similar to magnesium batteries tested earlier.[1] After partial usage, delivered capacity is highly dependent upon discharge temperature and storage.

The effects of discharge temperature upon BHARAT battery performance during continuous usage (Table 1 and Fig. 2) are typical of the present magnesium/manganese dioxide battery system. Below 21.1°C, the detrimental effect of discharge temperature is 21.9 times greater than at higher temperatures.

Table 1. Effects of discharge temperature on average service life (continuous discharge).

Discharge Temperature (°C)	BHARAT Battery Average Service (Hrs)	Rayovac Battery Average Service[1] (Hrs)
-17.8	20.1	18.5
4.4	44.4	45.4
21.1	70.4	65.9
43.3	71.7	68.5

Performance comparison of the two types of magnesium batteries (Fig. 3) demonstrates slight variations between them. Overall, when compared with Rayovac's performance, BHARAT battery performance is no more than 8.6 percent greater.

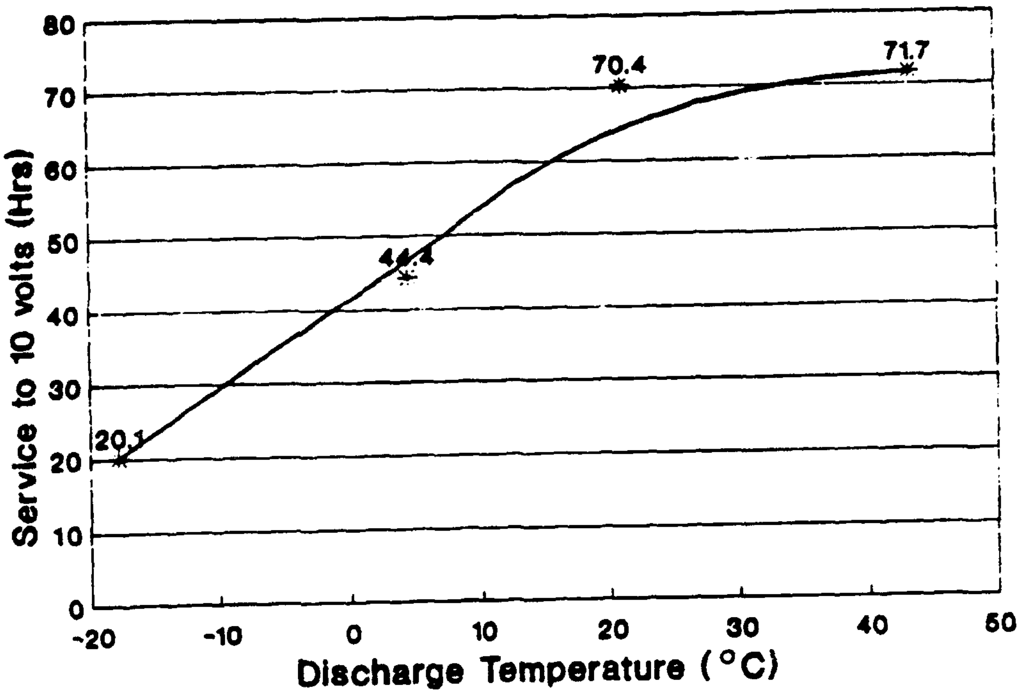

Figure 2. Effects of discharge temperature upon BHARAT battery continous performance (AN/PRC-77 simulation).

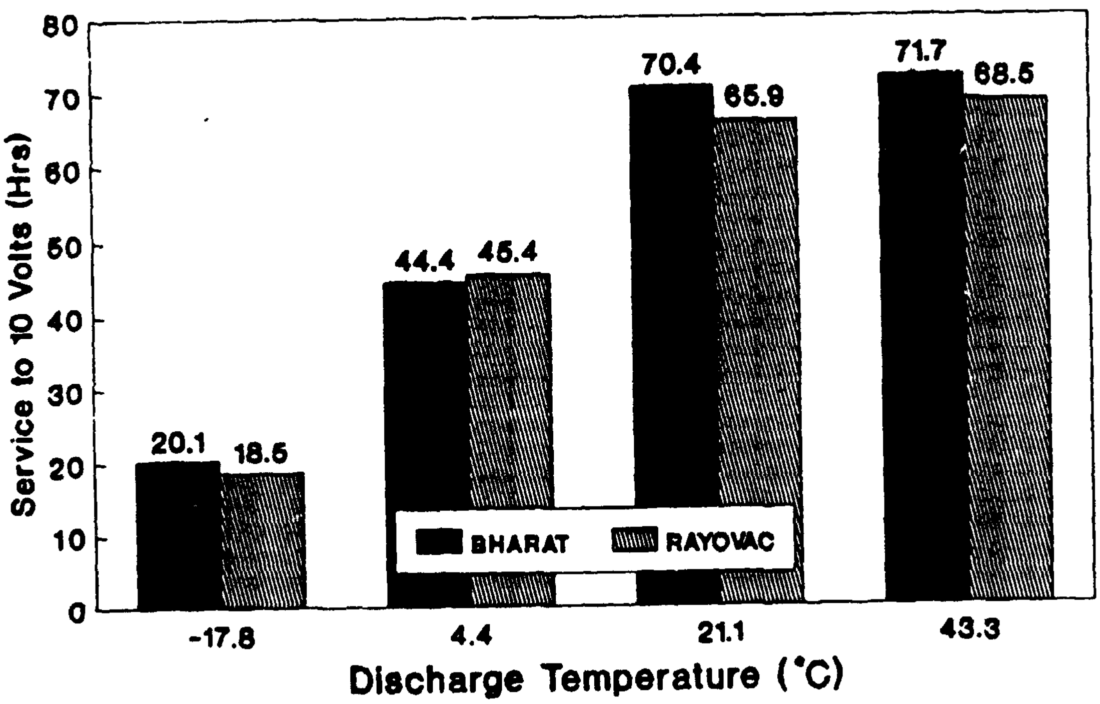

Figure 3. Continuous discharge performance comparison (AN/PRC-77 simulation).

The effect of intermittent usage on BHARAT battery performance (Table 2 and Fig. 4) is similar to that of earlier testing of the Rayovac battery.[1] Following the removal of the protective magnesium hydroxide (MgOH) anode film, the anode is unprotected during initial discharge. The film does not re-form to its original passivity[2,3]; therefore, anode corrosion begins, thus reducing available battery capacity.

Table 2. Effects of intermittent usage on service loss (four weeks of storage following partial discharge).

Discharge Temperature (°C)	BHARAT Battery Intermittent Service (Hrs)	BHARAT Battery Service Lost (Hrs)	Rayovac Battery Intermittent Service (Hrs)[1]	Rayovac Battery Service Lost (Hrs)
-17.8	8.7	11.3	6.2	12.3
4.4	18.0	26.4	19.4	26.0
21.1	44.0	26.4	47.5	18.4
43.3	45.2	26.5	43.5	25.1

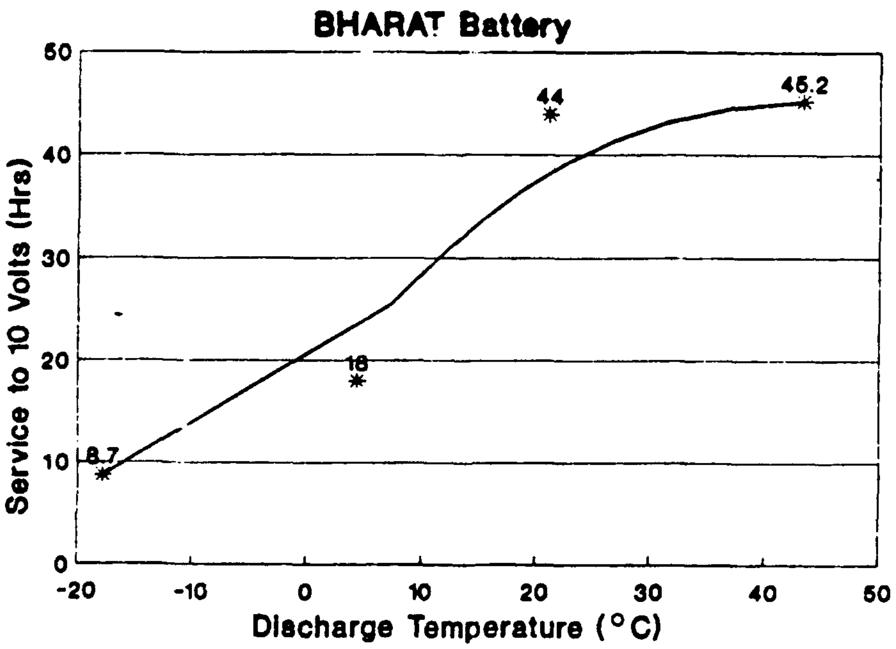

Figure 4. Effects of intermittent usage (four weeks storage, AN/PRC-77 simulation).

Intermittent performance comparison (Fig. 5) show insubstantial performance differences between the two battery types. Only -17.8°C is the performance differential between the two battery types substantial (40.3 percent). Throughout the remaining temperature profile, battery performance differential is no greater than 7.4 percent.

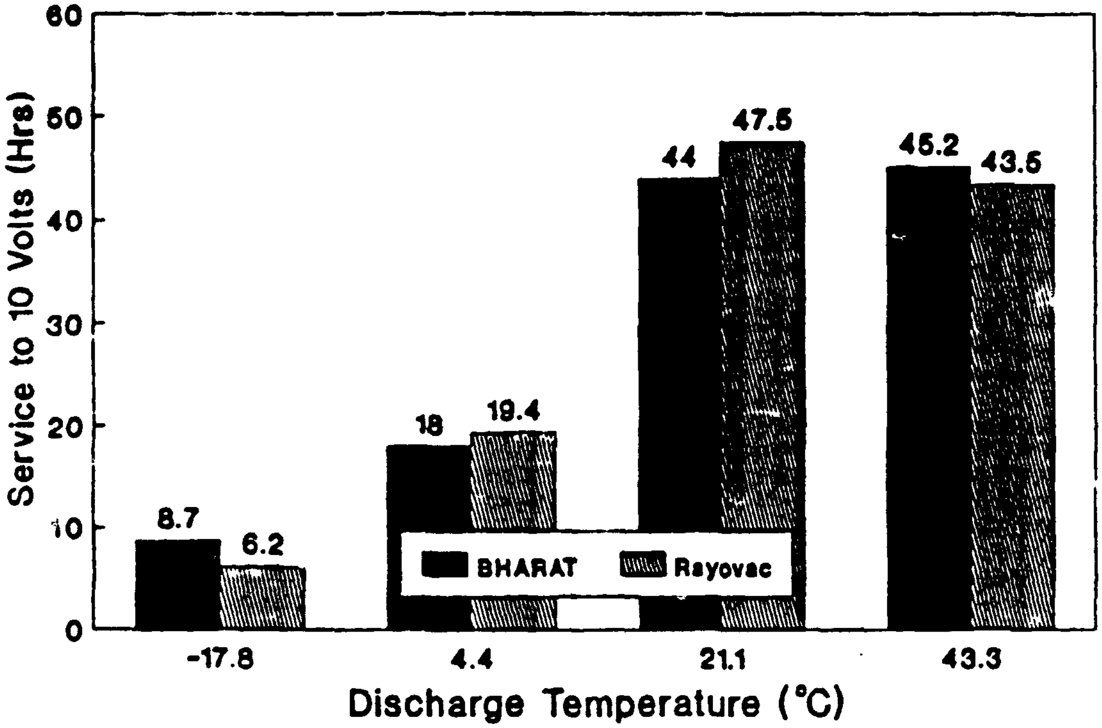

Figure 5. Intermittent discharge comparison (four weeks storage, AN/PRC-77 simulation).

Each of the ten BHARAT batteries was within the weight requirement (Table 3), as noted in the magnesium BA-4386 battery specification (MIL-B-55252). Dimensionally, battery lengths measured greater than the allowable maximum value. Initially, the length of nine batteries exceeded the limit; after discharge, the length of the ten batteries exceeded the limit.

After discharge, post-mortem analyses of the batteries revealed that the individual cells "bulged." This swelling was caused by the formation of MgOH, a by-product of anode corrosion, between the anode and cathode, and resulted in an outward force on the cans; eventually, the stress caused them to bulge.

Table 3. BHARAT Battery Weights and Dimensions

Battery Number	Weight (kg)	Initial Dimensions (mm)			Final Dimensions (mm)		
1	1.195	89.22	53.78	241.5*	89.69	55.22	244.0*
2	1.182	89.18	53.86	241.5*	89.21	53.92	242.0*
3	1.193	89.79	52.96	241.5*	89.54	52.74	243.5*
4	1.185	89.15	53.41	241.5*	89.15	53.55	241.5*
5	1.206	89.52	53.35	241.5*	89.35	53.33	241.5*
6	1.196	89.63	53.76	241.5*	89.62	53.80	242.0*
7	1.185	89.39	53.72	241.0	89.36	53.54	242.0*
8	1.203	89.82	53.86	241.5*	89.71	53.92	242.5*
9	1.201	89.12	53.13	241.0	89.15	53.50	242.5*
10	1.184	89.99	53.20	241.5*	89.80	53.23	242.0*
MIL-B55252 Specification (Maximum)	1.361	92.08	53.98	241.3	92.08	53.98	241.3

*Dimension Exceeded Specification Limit.

CONCLUSIONS

Performance characteristics of the BHARAT batteries are similar to those of the Rayovac batteries. Delivered capacity of the two battery types decreased with decreasing discharge temperature. After partial usage, both battery types underwent anode corrosion during storage. This reduced the available capacity substantially.

Overall, continuous and intermittent battery performance of the two manufacturers is similar. (See Figs. 3 and 5.) Based solely on performance, no appreciable advantage is achieved from utilization of the BHARAT magnesium battery.

REFERENCES

1. G. DiMasi, L. Jarvis, M. Brundage, T. Atwater, "Comparison Electrical Testing of the BA-4386/U Magnesium and the BA-5590 Lithium Batteries," LABCOM Technical Report, SLCET-TR-86-13 (1986).

2. G.S. Lozer and R.J. Ryan, "Magnesium Primary Cells," 16th Power Sources Symposium (1962).

3. D. Linden, in Handbook of Batteries and Fuel Cells, (McGraw-Hill, New York, 1984), pp. 6,7.

4. L. Jarvis, "The Beneficial Effect of Increased Cathode Water Content on Mg/MnO_2 Battery Performance," J. Power Sources 32, 271-276 (1990).

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